

Research article

Concurrent and Construct Validation of a Scale for Rating Perceived Exertion in Aquatic Cycling for Young Men

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Abstract

Aquatic cycling is a program of physical exercises performed with immersed stationary bikes. Few studies have provided evidence about the intensity control during its practice. Therefore, the primary aim of this study was to examine the concurrent and construct validity of a new scale for rating perceived exertion (RPE) during aquatic cycling in young men. Thirty physically active, healthy young men performed a load-incremented aquatic cycle ergometer protocol. Concurrent validity was established by correlating the Aquatic Cycling Scale (ACS) with oxygen uptake, pulmonary ventilation (VE), heart rate (HR), and blood lactate concentration (BL) responses to the maximal load-incremental test. Construct validity was established by correlating RPE derived from the Aquatic Cycling Scale (0–10) from the Borg Scale (6–20). RPE-overall, maximal oxygen uptake (VO_{2max}), oxygen uptake indexed to body weight (VO_2), VE, HR, and BL were measured during each exercise stage. The range of exercise responses across the incremental test were $VO_{2max} = 1.07\text{--}3.55$ L/min, $VO_2 = 14.26\text{--}46.89$ ml/Kg/min, $VE = 23.17\text{--}138.57$ L/min, $HR = 99.54\text{--}173.31$ beats/min, $BL = 1.18\text{--}11.63$ mM, ACS RPE-overall = 1.11–9.33. Correlation/regression analyses showed ACS RPE as a positive linear function of VO_{2max} ($r = 0.78$; $p < 0.05$), VO_2 ($r = 0.87$; $p < 0.05$), VE ($r = 0.86$; $p < 0.05$), HR ($r = 0.77$; $p < 0.05$), and BL ($r = 0.85$; $p < 0.05$). RPE-ACS distributed as a positive linear function of the RPE-Borg Scale ($r = 0.97$; $p < 0.05$). ANOVA indicated that an incremental pedalling cadence of 15 revolutions per minute (rpm) provoked significant differences ($p < 0.05$) regarding previous stages in the majority of the variables analysed. The Aquatic Cycling Scale is an appropriate tool for monitoring exertion intensity during aquatic cycling in fit men. A brief increment in aquatic pedalling cadence of 15 rpm increases the intensity of the aquatic pedalling exercise.

Key words: Perceived effort, intensity monitoring, maximum oxygen consumption, pulmonary ventilation, heart rate, blood lactate.

Introduction

Physical activities in water have become extremely varied in recent years, resulting in a noticeable increase in the number of participants of different age groups, physical conditioning levels, and specific clinical needs (Rewald et al., 2016; 2017). These activities can be appropriate for exercising on different settings and with different purposes, i.e., recreational and fitness practitioners, physical conditioning activities to sports and physical therapies, etc. (Asimena et al., 2013; Bocalini et al., 2017; Dannaway et al., 2016; De Carlo and Armstrong, 2010; Kim et al., 2010; Prado et al., 2016). Water activities provide

many benefits, including increased motivation to exercise, reduction of ground impacts in joints, and improvement in the physical training stimulus (Dionne et al., 2017; Frangolias and Rhodes, 1996). Some of these benefits are due to unique and specific properties that the aquatic environment offers in comparison to those derived from the terrestrial environment, such as buoyancy, hydrostatic pressure, and drag force (Brasil et al., 2011; Chu and Rhodes, 2001; Dionne et al., 2018).

In general, these attributes of water activities have triggered a rising interest in studies aiming to confirm their health, rehabilitation, and physical conditioning benefits (Borreani et al., 2014; Colado and Triplett, 2009; Colado et al., 2012a). The acute and chronic physiological responses to traditional aquatic activities such as swimming, (Becker, 2011; Santhiago et al., 2011), exercises in deep (Killgore et al., 2010; Meredith-Jones et al., 2011) and shallow water (Meredith-Jones et al., 2011; Pinto et al., 2011; Raffaelli et al., 2010) are already readily reported in the literature, but this is not the case for new emerging activities such as aquatic cycling.

Aquatic cycling activities using stationary immersible bicycles can be done individually or in groups, and their popularity is increasing worldwide (Rewald et al., 2017). The purpose of these activities is to maintain or increase cardiorespiratory fitness, while participants are sitting with their chests immersed and continually pedalling against the water resistance (Brasil et al., 2011). Some upper body exercises can also be added if required, i.e. one or two limbs are not holding in the bike handlebars and pushing and pulling against water with quick movements (Rewald et al., 2016). Thus, aquatic cycling activities are being recommended by health-fitness practitioners and scientists for various purposes in both sports and therapeutic settings (Brasil et al., 2011; Dionne et al., 2017; Rewald et al., 2016).

There are only a few scientific studies that have examined the acute and chronic effects of aquatic cycling (Di Masi et al., 2007; Garzon et al., 2015; Giacomini et al., 2009; Rewald et al., 2016; Yazigi et al., 2013). Control of the exercise intensity using physiological, psychological, or performance variables is a key factor in ensuring safety, efficacy, and individuality of the physical activity in any type of population, both on dry land and in the water environment (ACSM, 2011; Dionne et al., 2017; Garzon et al., 2015; Rewald et al., 2017). However, only a few studies have analysed the criteria for objectively monitoring intensity during aquatic cycling and with different brands of exercise cycles (Garzon et al., 2017; Giacomini et al.,

2009; Yazigi et al., 2013). In aquatic cycling, intensity depends on the resistance that the water provides as a function of pedals and/or paddles movement through a fluid medium, and the level of this resistance depends mainly on the pedalling cadence, body position (Dionne et al., 2018; Garzon et al., 2015), seat height, the precise characteristics of the pedal system, and the leg anthropometrics of the participant (Garzon et al., 2015).

Unfortunately, most aquatic stationary bicycles do not facilitate measuring the load/resistance employed by the practitioners during their training. Often the practitioner perceives the load merely as a resistance, without being able to measure it or even control pedalling cadence to produce a target load. This is because there is no load resistance control system similar to that in land-based cycling. Thus, in these cases, heart rate and rating of perceived exertion (RPE) are the most often used parameters for monitoring and regulating intensity during aquatic cycling training sessions (Alberton et al., 2011). In certain situations it is not possible to control the intensity of exercise through physiological variables. In such situations, RPE is a valid indicator of exercise intensity due to its direct relation with such physiological mediators as blood lactate (BL), muscular activity (i.e. EMG), heart rate (HR), oxygen uptake (VO_2), and pulmonary ventilation (VE) (Colado et al., 2014).

Thus, in view of the difficulty of monitoring and regulating intensity of aquatic cycling, it became necessary to demonstrate that the RPE could be applied correctly during aquatic pedalling activities in the semi-recumbent position through a validation of the concurrent type (Robertson et al., 1995; 1996). Even more necessary if it is taking in account the possible influence of the specific physical properties of the aquatic medium (i.e. buoyancy, hydrostatic pressure, and drag force) on physiological and psychological responses (Chu and Rhodes, 2001). However, cycling in the semi-recumbent position differs from that in a vertical position, and the change in body position could result in different physiological responses, as for example a heart rate decrement due to facilitation of the venous return (Volianitis and Secher, 2009; Yoshiga and Higuchi, 2002; Yoshiga et al., 2003). Consequently, to date, it remains unclear whether it is possible to use RPE to regulate exercise intensity during water cycling for positions in the fully vertical sitting. It should be emphasized that currently, most aquatic cycling activities are performed in the fully vertical sitting position (Giacomini et al., 2009). Another point to accentuate is that although there is a pictogram for monitoring intensity during adult stationary-bicycle activities on land (Robertson et al., 2004), a pictogram for aquatic cycling needs to be validated by considering not only the specific images of this activity (showing the exerciser in an aquatic bike with swimwear) if not also its determinate point of deflection of the aerobic effort toward anaerobic (Pinto et al., 2016). This fact should be taken in account because the perceptual relationship with the physiological variables is not always completely linear, and for this reason the usual incremental linear representation in the scales could be less accurate (Kruel et al., 2013).

Hence, a new scale was designed for monitoring aquatic cycling activities performed in the fully vertical sitting position (Figure 1). This new aquatic cycling scale (ACS) has a category rating format that contains a pictorial positioned along a comparatively narrow numerical response range, 0–10 (Figure 1). The exertional meaning of each pictorial descriptor is consonant with its corresponding numerical descriptor, i.e. the faces shows an increment of the exercise intensity (no fatigue to maximum fatigue) associated with a higher numerical value (0–10). To validate this new pictogram, a concurrent validation must be performed, wherein RPE should be correlated to the performance and/or physiologic variables (Nakamura et al., 2009). Moreover, a construct validation must also be performed, wherein the RPE of the new scale (conditional scale) should be correlated with the one obtained from a previously validated scale (criterion scale).

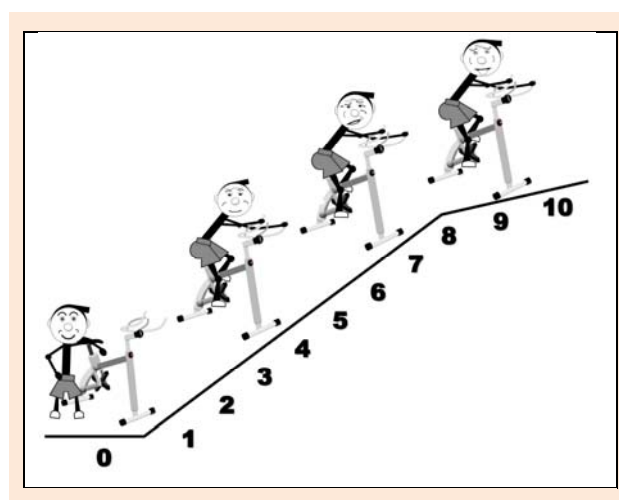


Figure 1. New scale for rating-perceived exertion during aquatic cycling.

Therefore, taking in account all these previous considerations, the objectives of this study were to examine the concurrent and construct validity of a new perceived exertion scale in young males performing aquatic cycling exercises using the VE, HR, and BL as the criteria or stimulus variables and the Borg (6–20) Perceived Exertion Scale as the criterion metric. It was hypothesized that the RPE derived from the new scale for aquatic cycling during a load-incremental aquatic cycle maximal test: (a) would distribute as a positive linear function with oxygen uptake, VE, HR, and BL responses for young adult men and (b) would be positively correlated with RPE derived from the Borg Scale. Increments of 15 revolutions per minute (rpm) in the aquatic-pedalling cadence was used to corroborate if it can produce a constant increment of the intensity of the aquatic-pedalling exercise measured through the maximal oxygen uptake (VO_{2max}). Thus, this hypothesis was that the resulting increase in pedal cadence would be consistent throughout the intensity range (i.e. a linear response). More specifically, it was hypothesized that a fixed increment in the aquatic pedalling cadence of 15 rpm would be positively correlated with an increment in the VO_{2max} and ACS RPE responses during the maximal load incremental test. If all these hypotheses are true this would be the first

study to provide an easy and specific tool to guarantee intensity control during performance of this aquatic activity. This new pictogram will allow clear differentiation of the intensity zones to which the participant could train during their aquatic-peddalling exercise.

Methods

Participants

A convenience sample of 30 male university students voluntarily participated in the study. Sample size was determined using G* Power 3.1 software (Faul et al., 2009). The calculation indicated 30 volunteers were necessary to meet the required power of 0.85, $\alpha = 0.05$, correlation coefficient of 0.5, nonsphericity correction of 1, and moderate effect size. This prior analysis of statistical power was performed to reduce the probability of type II error and to determine the minimum number of participants required for this investigation to reject the null-hypothesis at the $p < 0.05$ level of confidence (Beck, 2013). The participants were physically active men, but there were no athletes or practitioners of aquatic cycling or any other cycling activities. They had no cardiovascular disease, osteoarticular history, or clinical, neuromotor, or cognitive contraindications for the performance of the physical tests. All subjects were regular physical exercise participants (>160 minutes per week) and non-smokers (ACSM, 2010). The subjects were carefully informed about the potential risks and discomforts of the project, and they signed a written consent form before their participation in the study. The Ethics Committee of the University (H1369642832747) approved this investigation, and the study protocol was in accordance with the Declaration of Helsinki of 1975, modified in 2008.

Procedures

Each subject participated in two sessions, consisting of familiarization and experimental protocol. The first familiarization session was conducted 48–72 hours before data collection during the experimental protocol. Several restrictions were imposed on the volunteers: no food, drinks, or stimulants (i.e., caffeine) to be consumed 3–4 hours before the sessions and no physical activity more intense than the usual daily activities of living 12 hours before. They were encouraged to sleep at least 8 hours the night before data collection. All measurements were conducted by the same investigators and were always performed in the same sports facility. A detailed description of the methods employed in this study has been published previously (Mays et al., 2010; Robertson et al., 2004; Utter et al., 2004). Thus, taking in account the previous indications of Robertson et al. (1996), the following is a summary of the methods that pertain specifically to the water immersion aspects of the over-all experimental.

Familiarization session

Each participant took part in the familiarization session using the aquatic bicycle (Hydrorider®, Bologna, Italy) with the exercise resistance produced by the four paddles on the pedalling mechanism set to the maximum length. Saddle height was adjusted after the participant sat on the bicycle

with the heel pressed on the foot pedal at the lowest point and the leg extended (Leone et al., 2014); hands positioned on the lower part of the handlebar, which characterizes position 2 in aquatic cycling (Brasil et al., 2011); and handlebar height remaining above saddle height. The proper immersion depth was set to the xiphoid process (chest-level immersion) (Yazigi et al., 2013), using for this the movable rails that the bicycles had in their support base which let move up and down the bicycle height.

According the strict criterions of previous studies (Mays et al., 2010; Robertson et al., 2004; Utter et al., 2004), the participants were instructed regarding the proper use of both perceived exertion scales by the investigators. The subjects separately viewed the Borg and the ACS scales when their respective instructional set was read. They were told to respond with numerical categories only about their undifferentiated overall body exertional perception using a hand signal for each scale. Scales were always positioned in full view in front of the subjects. Due to this study used a continuous load-incremental maximal test, in the familiarization session all procedures were carefully explained to avoid that physical performance could be subconsciously decreased when fatigue came. For reducing this risk, also subject's maximal conscious effort was always required and researchers supported the test with external encouragement (Lambert et al., 2005; Wittenkind et al., 2011).

Participant's height was determined using a portable stadiometer (IP0955, by Invicta Plastics Limited, Leicester, United Kingdom). Total body mass and percentage of fat was measured by bioelectric impedance analysis (Body Composition Analysis, Tanita BF-350, Tanita Corp., Tokyo, Japan) according to previous studies and procedures (Colado et al., 2013). Participants were instructed to wear shorts or men's swim trunks and specific footwear (i. e. aquatic socks) (Athletech, USA). The subjects then cycled on the aquatic bicycle at different progressive cadences, similarly to the test that was used during the experimental protocol session. While pedalling, subjects also wearied the gas collection mask to be familiarized with its use. All technical details that must be taken in account while this exercise is performed were previously explained.

Experimental protocol session

The participants were subjected to a continuous load-incremental maximal test by changing the pedalling cadence, which was controlled by a digital acoustic metronome (recorded on a compact disc). The water cycling maximal test started at a rate of 100 beats per minute, with an initial stage of 3 minutes and with subsequent increments every 2 minutes of 15 beats per minute in the aquatic pedalling cadence until reaching exhaustion (Pinto et al., 2016). The subjects were advised to perform one complete pedalling cycle (i.e., 0–360°) in 1 beat, considering that the beat is a steady pulse that is repeated cyclically during one minute and this determine the pace of the movement (for example, 100, 115, 130, etc. beats or pulses per minute). This aspect is usually employed during aquatic cycling activities when music is used for monitoring the exercise intensity thought

the pedalling cadence. Therefore, a complete pedalling cycle of 360° has been considered as the equivalent to a revolution per minute in our study. A researcher was always in the water checking visually that this was strictly adhered to, in this way it was guaranteed an uniform change in load-incremental maximal test (Borreani et al., 2014; Colado and Triplett, 2009; Colado et al., 2013).

Using the procedure of Pinto et al. (2016) during the aquatic exercise, the participants were connected to a portable metabolimeter (K4b2; Cosmed, Rome, Italy) that measured the $\text{VO}_{2\text{max}}$ (L/min) and VO_2 indexed to body weight (ml/kg/min), and pulmonary ventilation (VE) (L/min) on a breath-by-breath basis. The metabolimeter was enclosed in a waterproof bag (Aquatrain; Cosmed, Rome, Italy) that was suspended in front of each participant. The gas analysers and the flow meter of the respiratory-metabolic instrument were calibrated before each test following the instructions of the manufacturer. According to Yazigi et al. (2013), HR (beats per minute) was measured by telemetry (Electro Oy, Polar, Kajaani, Finland) during the entire test, and a blood sample was collected from the earlobe each two stages of the test, and BL (mM) was analysed by a portable lactate analyser (Lactate Pro; Arkray Inc., Japan).

Water temperature higher 30° C provokes less thermal comfort and limit tolerance to cycling exercise likely caused by increased thermal load (Yazigi et al., 2013). However, if the exercise is performed in thermoneutral water it is known that subject's RPE may be an effective index for the intensity prescription in the same way that it is for land activities (Fujishima and Shimizu, 2003). So, throughout the experiment, both air and water temperatures were maintained thermoneutral at 24° C and 30° C, respectively (Alberton et al., 2011; Pinto et al., 2015; Pöyhönen et al., 2002).

RPE's from the two scales were recorded in counterbalanced order during the last 30 seconds of each stage of protocol. For both scales, perceived exertion was defined as the subject's intensity of effort, strain, discomfort, and/or fatigue felt during the exercise, representing the overall body (undifferentiated body regions) (Noble and Robertson, 1996; Pinto et al., 2016). The test was terminated when: a) the participant stopped voluntarily owing to exhaustion, b) the investigator detected that the participant was not keeping up with the fixed pedal rate in the pertinent stage, i.e., if he left the rhythm for 10 consecutive seconds, or c) the participant stopped when he used a hand signal to indicate exhaustion. In addition, the assessment was considered valid when any of the following criteria were met at the end of the test: average time ranged from 8 to 10 minutes, RPE at least 18 on Borg's 6–20 RPE scale, respiratory exchange ratio (RER) >1.15, and maximal respiratory rate of at least 35 breaths per minute (Pinto et al., 2016).

Statistical analyses

The statistical analyses were performed using commercial software (SPSS, Version 24.0; SPSS Inc., Chicago, IL). Descriptive data for perceptual and physiological variables were calculated as mean \pm standard deviation (SD).

Continuous outcome variables were assessed for normality. Scatter plots were developed to identify outliers and to determine whether a linear trend was observed between the following variables across stages of the maximal load incremental test: VO_2 , VE, HR, and BL and the RPE from the Borg and the Aquatic Cycling scales. Correlation and regression analyses of data from the final minute of each of the maximal load-incremental test stages of the $\text{VO}_{2\text{max}}$, pedalling cadence and ACS RPE-overall were initially used to check whether the increment of the aquatic pedalling cadence corresponded with an increment in the intensity of the exercise (Yazigi et al., 2013). Evidence for both concurrent and construct validity was determined using linear regression analysis with repeated measures data derived from each stage of the maximal load-incremental. When testing concurrent validity, the analysis separately regressed VO_2 , VE, HR, and BL against ACS RPE-overall using data from the final minute of each of the maximal load-incremental test stages. VO_2 , VE, HR, and BL were compared separately with the RPE using correlation analyses accounting for clustering (stages nested within subjects) throughout the wide range of exercise intensities from the graded exercise test. A simple logarithmic regression analysis were used for verified if the nonlinear design of the new ACS pictogram was appropriate. When testing construct validity, the analysis regressed ACS RPE against the Borg Scale RPE by using data from each of the maximal load-incremental test stages. An analysis of variance (ANOVA) with one-factor repeated measures was performed to determine the existence of possible differences between the stages of pedalling cadences (different intensities) and their respective responses in all physiologic and psychological variables. A post hoc analysis with Bonferroni correction was used in the case of significant differences in the ANOVA model. The level of statistical significance was set at $p < 0.05$.

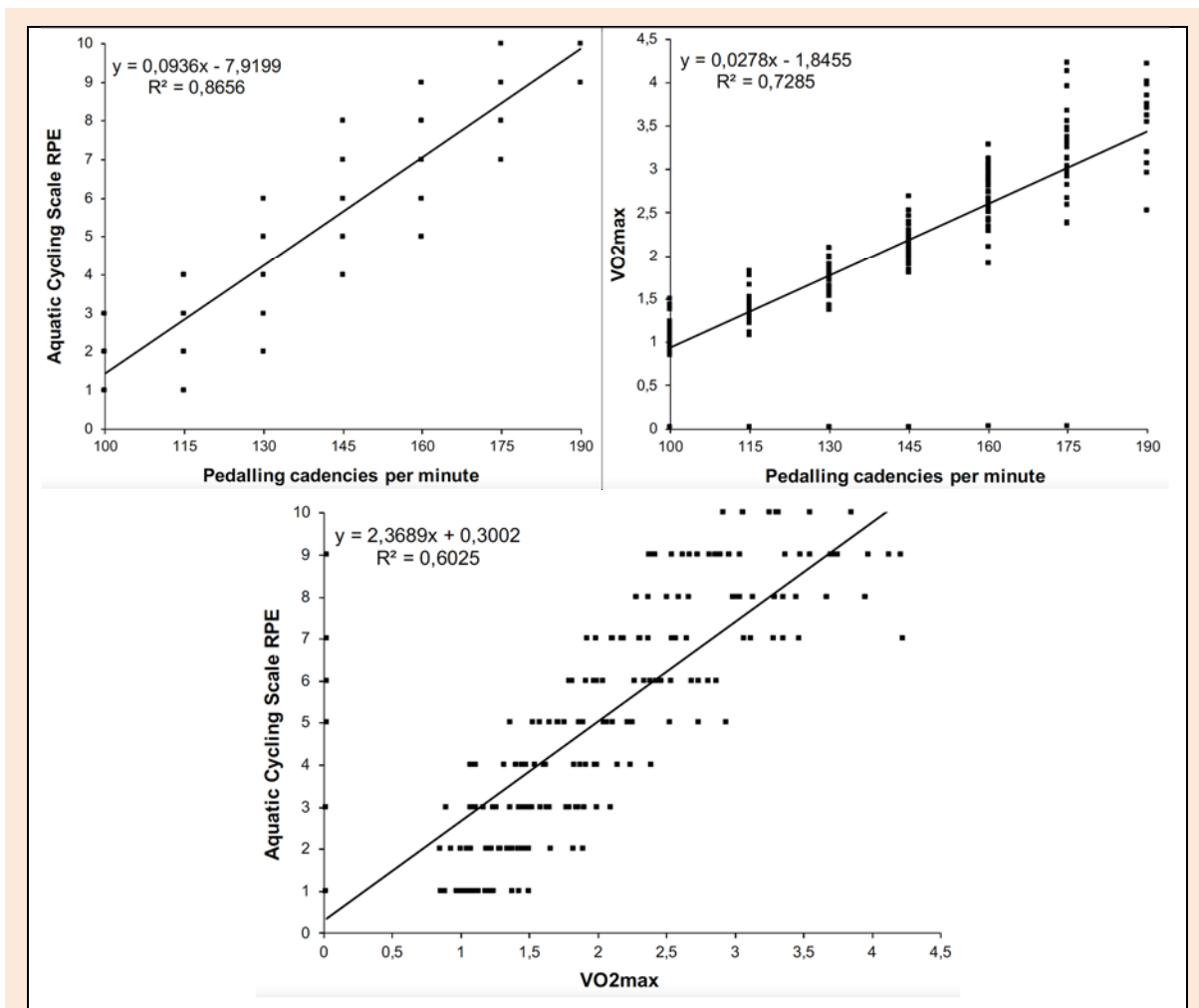
Results

The 30 male subjects of the present study had the following demographic characteristics: age: 22.37 ± 2.31 years old; height: 1.77 ± 0.07 m; body mass: 72.95 ± 7.78 kg; and body fat percentage: $14.84 \pm 3.50\%$. None of the enrolled subjects abandoned the study during its course, and none of them stopped the test due to any negative clinical symptoms such as chest pain, heart palpitations, or nausea. The means (\pm SD) of selected physiological variables and the Borg and aquatic cycling ratings of perceived exertion during the maximal load incremental aquatic cycling test are presented in Table 1. The stages of pedalling cadences per minute (rpm) showed a high significant positive relationship with the ACS RPE ($r = 0.93$, $p < 0.05$) and with the $\text{VO}_{2\text{max}}$ ($r = 0.85$, $p < 0.05$), while ACS RPE and $\text{VO}_{2\text{max}}$ also demonstrated a good significant positive relationship ($r = 0.78$, $p < 0.05$). Their respective values from regression analysis are shown in Figure 2, while the percentage of the $\text{VO}_{2\text{max}}$ increment ($\Delta\%$) regarding previous pedalling cadence stages is shown in Table 1. The $\Delta\%$ was calculated with the standard formula: $\text{change} (\%) = [(\text{value of the pedalling cadence stage} - \text{value of the previous pedalling cadence stage}) / \text{value of the previous pedalling cadence stage}] \times 100$.

Table 1. Descriptive responses for selected physiological variables and ratings of perceived exertion (mean \pm SD) and percentage of increment regarding previous pedalling cadencies stages along the maximal load incremental test.

Pedalling cadence stages							
Pedalling cadence (bpm)	100	115	130	145	160	175	190
VO₂max (L/min)	1.07 (0.18)	1.39 (0.21)*	1.73 (0.21)*	2.13 (0.22)*	2.60 (0.38)*	3.24 (0.47)*	3.55 (0.48)#
$\Delta\%$		29.90	24.46	23.12	22.06	24.61	9.57
VO₂ (ml/kg/min)	14.26 (2.66)	18.50 (3.35)*	22.95 (3.36)*	28.28 (3.03)*	34.42 (4.54)*	42.98 (6.85)*	46.89 (5.64)#
$\Delta\%$		29.73	24.05	23.22	21.71	24.86	9.10
VE (L/min)	23.17 (5.11)	30.56 (4.70)*	40.82 (5.50)*	52.20 (5.51)*	68.73 (9.79)*	97.03 (12.92)*	138.57 (13.12)*
$\Delta\%$		31.89	33.57	27.88	31.66	41.78	42.81
HR (bpm)	99.54 (14.98)	105 (18)	116 (23)	133 (20)*	149 (21)*	162 (24)*	173 (28)*
$\Delta\%$		5.56	10.17	14.81	11.98	8.9	6.93
BL (mM)		1.18 (0.43)		2.68 (1.03)		11.15 (2.22)*	11.63 (1.63)*
$\Delta\%$				97.32		88.85	88.37
ACS RPE	1.11 (0.33)	2.22 (0.83)*	3.1 (0.78)*	4.5 (0.73)*	6.22 (0.97)*	7.67 (0.71)*	9.33 (0.50)*
$\Delta\%$		100	39.64	45.16	32.22	23.31	21.64
Borg Scale RPE	7.55 (0.88)	9.33* (0.87)	11.33 (1.12)*	13.22 (1.20)*	15.22 (0.97)*	17.00 (0.71)*	19.00 (0.71)*
$\Delta\%$		23.58	21.44	16.68	15.13	11.69	11.76

SD: standard deviation. bpm: beats per minute. $\Delta\%$: increment percentage regarding value of the previous stage. The $\Delta\%$ was calculated with the standard formula: $\text{change (\%)} = [(\text{value of the pedalling cadence stage} - \text{value of the previous pedalling cadence stage}) / \text{value of the previous pedalling cadence stage}] \times 100$. VO₂max: maximum oxygen consumption. VO₂: oxygen uptake taking in account bodyweight; VE: pulmonary ventilation. HR: heart rate. BL: blood lactate. RPE: overall body rating perceived exertion from Borg or Aquatic Cycling scales (ACS). *: Significant difference ($p < 0.05$) regarding value of the previous stage. #: Trend of difference ($p = 0.12$) regarding previous stage.

**Figure 2.** Simple linear regression analysis between (i) Aquatic Cycling Rating of Perceived Exertion and maximal oxygen uptake (VO₂max) (L/min); VO₂max in each stage of pedalling cadencies per minute from the load incremental test, and (ii) Aquatic Cycling Rating of Perceived Exertion and VO₂max along all the maximal load incremental test.

stage] x 100. The ANOVA indicated significant main effects in stages of pedalling cadences per minute for ACS RPE ($F_{6,48} = 356.41$, $p < 0.05$, and $\eta^2 = 0.98$) and for VO_{2max} ($F_{1.78,21.42} = 227.17$, $p < 0.05$, and $\eta^2 = 0.95$). The stages of pedalling cadences per minute x ACS RPE interaction effect was significant for all the different stages (100, 115, 130, 145, 160, 175, 190 rpm); a similar result was observed for the VO_{2max} between all cadences, except for 175 and 190 rpm ($p = 0.12$). Table 1 shows the mean value percentages of the VE increment regarding previous pedalling cadence stages with a significant difference between all cadences. Table 1 shows similar results with VO_2 , except for 175 and 190 rpm ($p = 0.12$). Table 1 also shows significant differences between cadences regarding the HR values, with an exception between the first two stages (i. e., between 100 – 115 rpm and 115 – 130 rpm). There were significant differences observed between all cadences in the AC or the Borg scales RPE scores (Table 1). Finally, Table 1 shows significant BL differences between all verified cadences.

Regarding concurrent validation, correlational analysis indicated ACS RPE values were distributed as positive linear functions of VO_2 , VE, HR, and BL. Some data points from physiologic variables appeared to be outliers and they

were replaced by an mean value of the close values (Aguinis et al., 2013). Pearson correlation analysis showed a highly significant positive relationship between physiologic variables and the ACS RPE: VO_2 $r = 0.87$; VE $r = 0.86$; HR $r = 0.77$; and BL $r = 0.85$. All correlational functions were statistically significant ($p < 0.05$). Figure 3 shows the values from the regression analysis, and Figure 4 shows the effect plot image of the relationship between the physiologic variables and the ACS RPE along the maximal load incremental test. Figure 5 also shows a significant positive relationship from logarithmic regression analysis between the majority of the physiologic variables and the ACS RPE.

In reference to construct validation, the ACS RPE was positively and linearly related to the Borg Scale RPE for data derived on a stage x stage basis during the maximal load incremental test (Figure 6). Pearson correlation analysis showed a highly significant positive relationship between RPE derived from both scales: $r = 0.97$ ($p < 0.05$). Therefore, perceptual responses derived from the Borg and ACS are similar, and as such, the values of one may be transposed from the values of the other. To facilitate transposition from one scale to the other, an RPE conversion chart is presented in Figure 7.

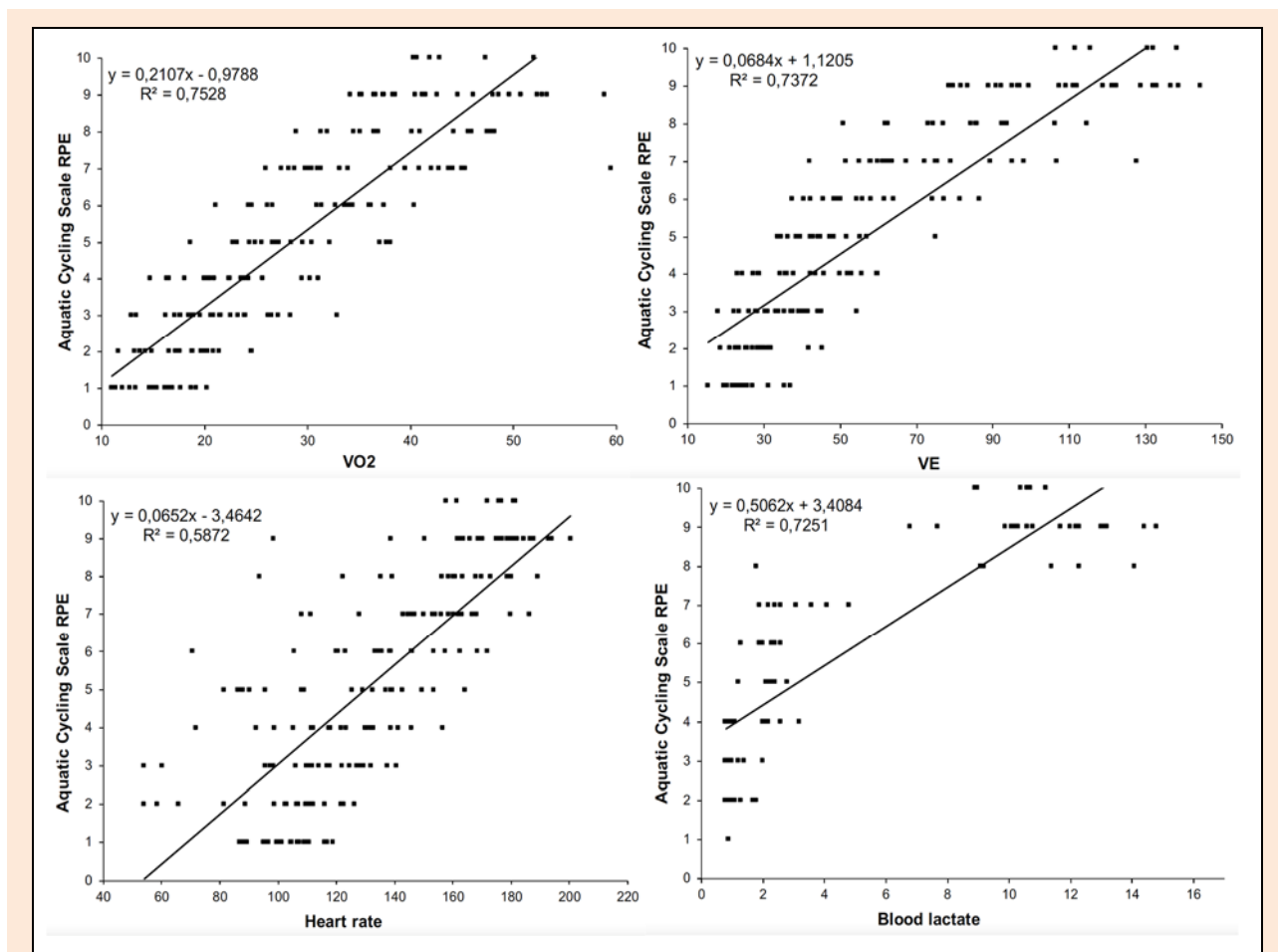


Figure 3. Simple linear regression analysis between the Aquatic Cycling Rating of Perceived Exertion and some of the different physiological variables along all the maximum load incremental test. VO_2 : oxygen uptake taking in account bodyweight (ml/kg/min); VE: pulmonary ventilation (L/min); Heart rate (beats per minute); Blood lactate (mM); Aquatic Cycling Scale RPE: overall body rating perceived exertion from the Aquatic Cycling Scale.

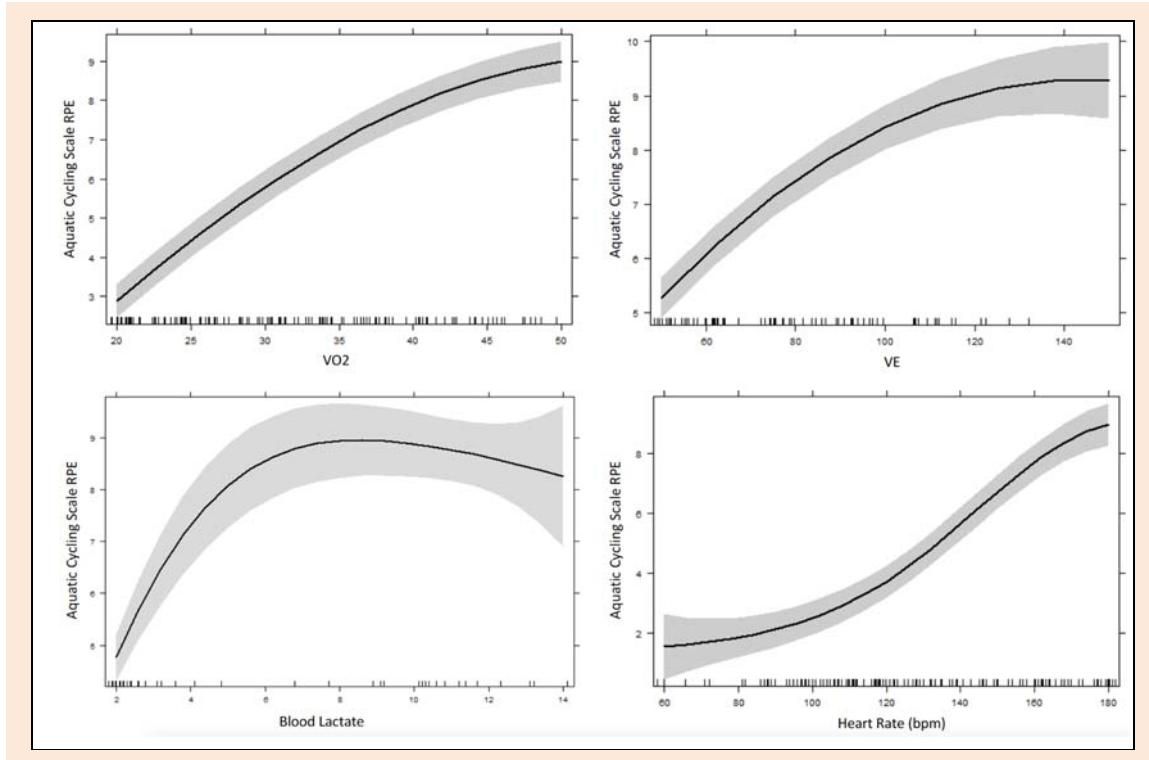


Figure 4. Effect plot image of the relationship between physiologic variables and the Aquatic Cycling RPE along the load incremental test. VO₂: oxygen uptake taking in account bodyweight (ml/kg/min); VE: pulmonary ventilation (L/min); BL: blood lactate (mM); bpm: beats per minute; RPE: overall body rating perceived exertion from the Aquatic Cycling Scale.

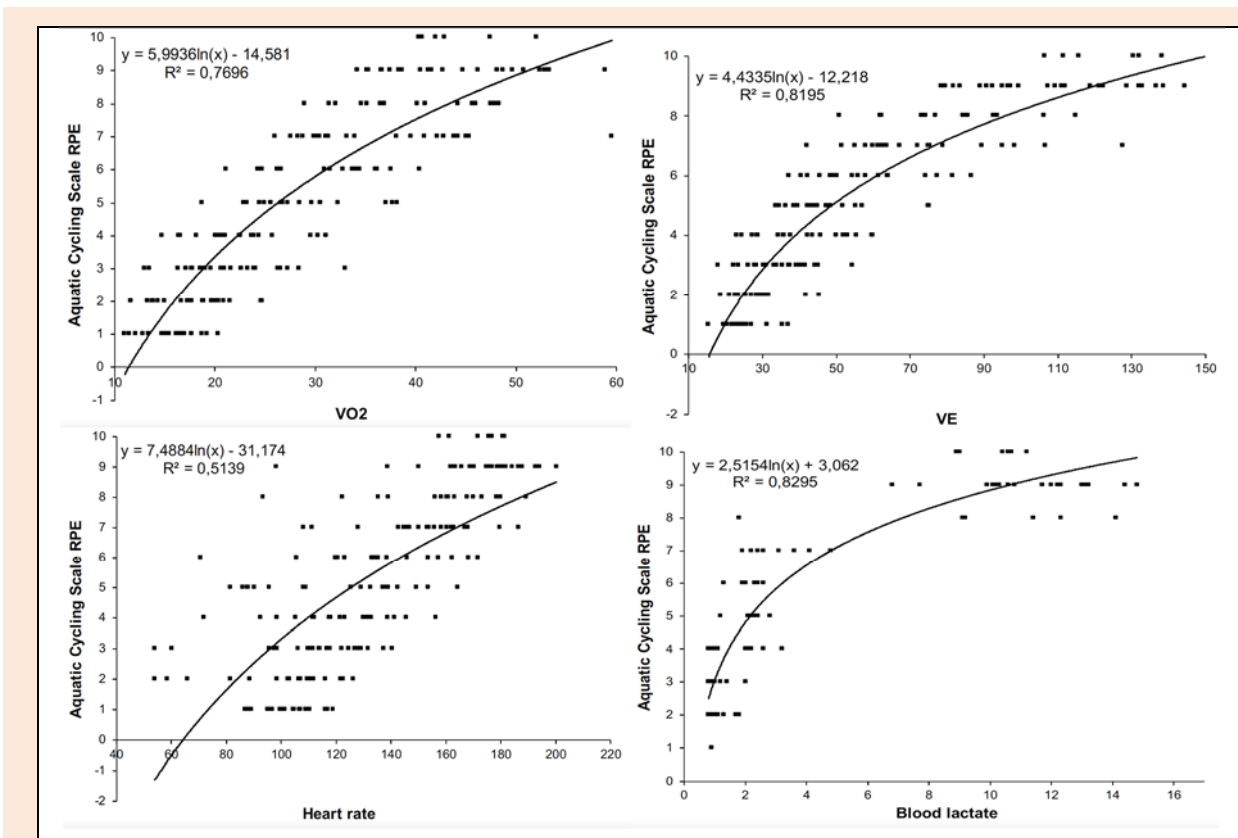


Figure 5. Simple logarithmic regression analysis between the Aquatic Cycling Rating of Perceived Exertion and some of the different physiological variables along all the maximum load incremental test. VO₂: oxygen uptake taking in account bodyweight (ml/kg/min); VE: pulmonary ventilation (L/min); Heart rate (beats per minute); Blood lactate (mM); Aquatic Cycling Scale RPE: overall body rating perceived exertion from the Aquatic Cycling Scale.

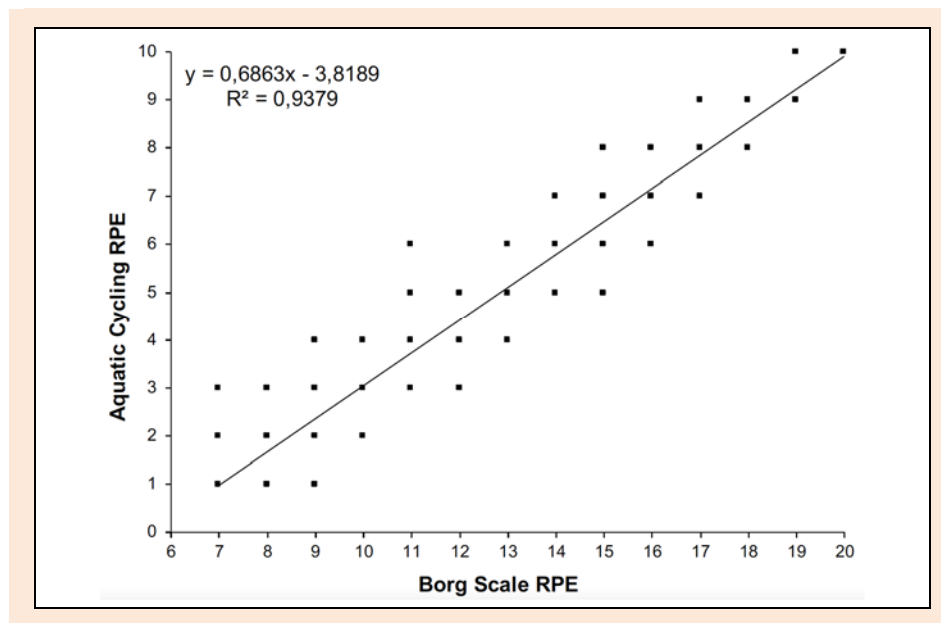


Figure 6. Simple linear regression analysis between perception scores of the Aquatic Cycling Scale and the Borg Scale along the maximal load incremental test.

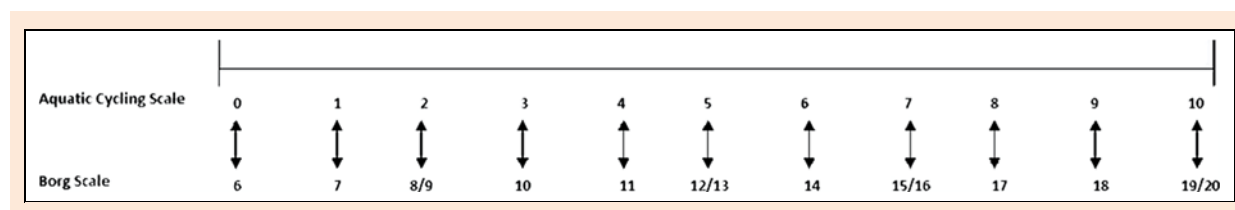


Figure 7. Ratings of perceived exertion conversion chart between the Aquatic Cycling and Borg RPE scales.

Discussion

There is substantial amount of scientific literature on the validity of specific RPE scales for different types of exercises (Colado et al., 2018; Nakamura et al., 2009; Robertson et al., 2004), and these studies frequently used the 6-20 category Borg Scale as the gold standard to establish measurement validity (Guidetti et al., 2011; Lagally and Robertson, 2006; Mays et al., 2010). Taking this into account, the most important finding of the present study was that the ACS is an appropriate tool for monitoring exertion intensity during aquatic cycling by young men, as demonstrated by the concurrent and construct analysis performed. Validation criteria stipulated that during the load incremental aquatic cycle maximal test, the RPE derived from the ACS would distribute as a positive linear function of VO_2 , VE, HR, and BL responses, and that the RPE derived from the ACS and Borg scales would be positively correlated. All the data obtained in the present study supported these concurrent and construct validity criteria. Additionally, it is known that a different pace of movement in water with the same device changes the resistance encountered during exercise, i.e., a higher pace of movement would increase the exercise intensity (Colado et al., 2013), as was the case with the increase of the pedalling rate in our study. As an example of the clear practical transfer of the utility of the ACS as validated in the present study is that among the current strategies applied as therapy for weight management and diabetes, low-impact aerobic exercises with different levels of exertion intensity are widely recommended

(Meredith-Jones et al., 2011). Therefore, aquatic cycle activities where this specific scale can be used for monitoring intensity could improve the safety and efficiency of their usage.

This significant increment of exercise intensity measured with the perceptual and physiological dependent variables was significantly correlated with an increment of the movement cadence in 15 rpm intervals. Therefore, it could be stated that the ACS can properly differentiate between different aquatic exercise intensities due to its significant correlation with all the different stages of pedalling cadence per minute. An increase of 10 bpm during aquatic cycling pedalling has been considered as adequate stimulus for incrementing physiologic responses (Yazigi et al., 2013), and the present study confirms these physiologic increases for changes at 15 bpm. Moreover, it also shows that the ACS is sensitive enough to determine increments in the perceived exertional signal consequent to these changes during an increment in the aquatic pedalling cadence.

The present study validates a perception effort system with immediate applicability for aquatic cycling, overcoming some specific limitations that previous validated scales could have had when applied to this specific aquatic activity (Robertson et al., 1996; Robertson et al., 2004). Hence, an important difference between the ACS and these previous RPE scales is the use of a specific pictorial with aquatic cycling descriptors and emphasizing it in the facial features associated with the intensity level of the required effort. This is because it has been demonstrated that adequate visual cues (i.e. understandable information for the

subject) can, at times, significantly improve comprehension scores (Rogers, 2006). So, ACS will be a proper tool for improving the quality of the intensity control during aquatic cycling activities.

These new specific aquatic pictorial descriptors were placed in juxtaposition with numerical classifications in a category scale format, taking into account previous studies which suggested that this could increase the effectiveness of the new scale for better learning results or less mental effort spent (Tabbers et al., 2004). This will facilitate its application for the different practical areas in which the ACS can be used. In addition, previous studies have suggested the need to adapt the pictorial design of the RPE scales to the reality of the physiological responses, proposing for this purpose, for example, the modification of the pictogram format in the resting position (Mays et al., 2010). As it has been considered in the present validation in which the pictogram for the resting position (0 RPE score) is a subject not exercising. Moreover, facial expressions, posture and dress are strong visual cues that can influence in the behavioural responses (Howlett et al., 2013). Thus, the new ACS also have taken in account dressing with swimwear the practitioner of the pictogram and to show a typical aquatic bicycle to transmit an accurate impression of an aquatic activity.

However, and much more recurrently for the RPE scales, researchers have always sought a better way to pictorially represent the increase in the intensity of effort during exercise. The development of these scales went from using horizontal representation (Eston et al., 2000) or vertical representation (Gros Lambert et al., 2001) to others that finally attempted to better represent the physiological reality of exercise by using a type of curvilinear representation (Eston and Parfitt, 2006), usually with fully linearly inclined representations (Robertson et al., 2000 and 2004). The category rating scale formats that have been developed traditionally to assess RPE are considered to be robust enough to evidence both linear and nonlinear response functions. However, sometimes an incremental linear representation could be less accurate visually if we consider that the perceptual relationship with the physiological variables is not always completely linear, where it could appear a possible saturation curve relationship, that is, despite the fact that there is a linear relationship in a large part of the range of values, a saturation at high intensities ends up occurring (Kruel et al., 2013). In this sense, and for aquatic cycling activities, Pinto et al. (2016) determined a deflection point at the anaerobic threshold, which was around the value of 8 RPE. Hence, the pictorial representation of the ACS in respect to other previous RPE scales has already included this modification in its design. As shown in Figure 4, this pictorial design is completely corroborated for ventilatory and lactate variables, while for HR, it has been partially corroborated due to its sigmoid relationship, as it was previously known (Trounson et al., 2017). The statistical significant values obtained in the logarithmic regression analysis, showed in Figure 5, also confirm the saturation curve relationship in a value close to 8 RPE for the majority of the physiological variables: VO_2 $r = 0.77$; VE $r = 0.82$; HR $r = 0.51$; and BL $r = 0.83$. So, it is

corroborate that the nonlinear design of the ACS could be an appropriate representation according to the real physiologic answers during the aquatic cycling activities.

Concurrent validity

Concurrent validation studies have been used extensively in the development of the OMNI Picture System of Perceived Exertion for distinct ages, genders, equipment, and cardiovascular or neuromuscular exercises (Colado et al., 2012b; 2014; Irving et al., 2006; Mays et al., 2010; Nakamura et al., 2009; Robertson et al., 2000; 2003; 2004; 2005; Utter et al., 2002). The RPE validation derived for the Omni Scales show an excellent correlation with the Borg Scale, which positively suggests that the Omni scales are an appropriate alternative for regulating indoor (dry land) exercise training (Robertson et al., 2004). However, it is not known whether this would be the case for aerobic exercise in an aquatic environment. The Aquatic Cycle Scale validated in our study appeared to be a useful tool for the regulation of exercise intensity because it showed strong correlation obtained with the criterion or response variables of performance in the same way as other previously reviewed studies, for instance, on the OMNI-Kayak Scale ($r = 0.91$) (Nakamura et al., 2009). Also with physiologic response variables, the strong correlation values obtained in the present study are in line with previous studies, for example, from the Adult OMNI Elliptical Ergometer RPE Scale (VO_{2max} $r = 0.94$; HR $r = 0.96$) (Mays et al., 2010), the Adult OMNI Scale RPE for Cycle Ergometer Exercise (VO_{2max} $r = 0.88$; HR $r = 0.87$) (Nakamura et al., 2009).

It is known that the relationship between the RPE and physiologic variables may be partially explained by the accepted fact that these physiological variables are important sensory cues for exertional perceptions (Nakamura et al., 2009). The linear regression models derived in the present investigation are consistent with previous validation paradigms (Guidetti et al., 2011), most of which used HR (Colado et al., 2014; 2018), BL (Irving et al., 2006; Robertson et al., 2003), or VO_2 (Robertson et al., 2005) as criteria measures. The present study found that the ratings of perceived exertion increased concurrently with corresponding increases in metabolic and circulatory responses. The strong positive relationship between the aquatic cycling RPE and physiological criterion variables is consistent with previous investigations that have used concurrent paradigms to validate other aquatic RPE indexes (Alberton et al., 2016; Morgan, 2001; Pinto et al., 2015). Thus, the forgoing validity evidence provided that the ratings of perceived exertion derived from the ACS are valid indicators of exercise intensities from low to high levels (Mays et al., 2010) during water immersion cycle ergometer exercise.

Construct validity

A limited number of studies have examined the construct validity of perceived exertion category scales (Lagally and Robertson, 2006). Some of them have used the Borg (6–20) Scale as a previously validated (i.e. criterion scale) (Mays et al., 2010; Nakamura et al., 2009). These previous investigations reported strong construct validity

correlations for the various conditional (i.e. new) RPE scales. For example, the Borg Scale (6–20) showed a good correlation with different new scales: (1) $r = 0.96$ Adult OMNI Elliptical Ergometer RPE Scale (Mays et al., 2010); (2) $r = 0.96$ Adult OMNI Scale of perceived exertion for walking/running exercise and the Borg Scale (Utter et al., 2004); (3) $r = 0.97$ Adult OMNI Scale RPE for Cycle Ergometer Exercise and the Borg Scale (Robertson et al., 2004); and (4) $r = 0.96$ OMNI-Kayak RPE Scale and the Borg Scale (Nakamura et al., 2009).

In the present study, the construct validity of the Aquatic Cycling Scale was established using the Borg (6–20) Scale (Borg, 1982) as the criterion metric. It was hypothesized that the RPE derived from the Aquatic Cycling Scale would be positively correlated with the Borg Scale RPE when perceptual estimates from both metrics were obtained during the same maximal load incremental aquatic cycling test. The validity coefficient between perceptual responses obtained from the two category scales was positive and strong ($r = 0.97$, $p < 0.01$). Thus, the findings supported the research hypothesis, establishing the construct validity of the ACS. Therefore, the comparatively high level of construct validity observed presently indicates that the ACS measures the same properties of an exertional percept as does the Borg (6–20) Scale when assessments are conducted for young adult men performing a maximal load incremental cycle test (Robertson et al., 2004).

Limitations

Although the present study was conducted exclusively with young men, previous studies have found that men and women rate their perception of exertion similarly when are examined at the same relative exercise intensity (Lagally and Robertson, 2006). Consequently, it might be assumed that this scale could also be applied to women with a profile of physical fitness and age analogous to that of the values of the subjects of our study. We suggest that new studies using the AC Scale in other populations should be conducted. It must be also highlighted that the RPE obtained in the present study associated to the anaerobic threshold is higher than has been generally noted for data derived from OMNI Scales (0–10) for both weight bearing and non-weight bearing exercise modes. It is known that anaerobic threshold is usually associated with 14 RPE on 6–20 Borg Scale (Purvis and Cureton, 1981), i.e., 6 RPE on 0–10 Scale (Lagally and Robertson, 2006). However, this RPE value could be a higher (7–8 RPE) to trained subjects, as in our study (Haskvitz et al., 1992). Moreover, an overall body perception to identify global cardiovascular fatigue was asked to subjects in our study, however it is possible that they also experienced a high fatigue from lower limbs working against the high aquatic drag forces in the last stages of the load-incremental test. This aspect maybe could have influenced in their global RPE. So, it should be recorded not only overall body RPE if not also chest and lower limbs RPE in order to have a better interpretation of the results obtained in future studies (Alberton et al., 2011; Okura and Tanaka, 2001).

Conclusion

Different paces are used during aquatic cycling activities (i.e., slow to fast pedalling), thus the exercise intensity fluctuate from low to high levels (Utter et al., 2004). Validation of the Aquatic Cycle Scale is necessary because it will add an easy monitoring tool for exercise testing, program workouts, or self-regulating intensity. The Aquatic Cycle Scale is a low-cost instrument with fast applicability and easy understanding that can contribute to the efficacy, safety, and, consequently, quality and efficiency in the prescription of exercises. Although this study considered the Aquatic Cycle Scale as an excellent intensity-control method for aquatic exercises, its utilization requires appropriate instruction and training. Nevertheless, it should be highlighted that the lack of familiarization with the scale may influence the perception results. So, according to the results of this study, this scale can be recommend for use in aquatic cycling by the professional providers of physical and rehabilitation exercises because it will ensure much more precise control of the activity being developed; hence, its effectiveness and safety will be warranted and the methodology improved.

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Key points

- Aquatic Cycling Scale (ACS) is a low-cost instrument with good visualization and fast applicability.
- ACS can be recommend for use in aquatic cycling by the professional providers of physical and rehabilitation exercises.
- ACS is an easy monitoring tool for exercise testing and self-regulation intensity.
- ACS could contribute to the efficacy, safety, and quality in the prescription of different long-term training programs.

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